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FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 218838US2PCT

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): 09/070429

INTERNATIONAL APPLICATION NO	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/04796	17 July 2000	None

TITLE OF INVENTION
AUTOMATIC GAIN CONTROLLER AND WIRELESS COMMUNICATION APPARATUS USING THE SAME

APPLICANT(S) FOR DO/EO/US
SAKIMA Nobuhiro

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
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9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
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22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Cited Reference (1)/Drawings (9 sheets)/Form PTO-1449

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10/070429	PCT/JP00/0796	218838US2PCT

24. The following fees are submitted..

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS PTO USE ONLY
☐	Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1040.00**
☒	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$890.00**
☐	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$740.00**
☐	International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$710.00**
☐	International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	9 - 20 =	0	x $18.00	**$0.00**	
Independent claims	5 - 3 =	2	x $84.00	**$168.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	

TOTAL OF ABOVE CALCULATIONS =	**$1,058.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.	**$0.00**	
SUBTOTAL =	**$1,058.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	**$0.00**	
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	Amount to be: refunded	$
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a. ☒ A check in the amount of **$1,058.00** to cover the above fees is enclosed.

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c. ☐ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **15-0030** A duplicate copy of this sheet is enclosed.

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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Surinder Sachar
Registration No. 34,423

22850

Surinder Sachar
SIGNATURE

Marvin J. Spivak
NAME

24,913
REGISTRATION NUMBER

March 18 2002
DATE

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PCT/JP00/04796	**17 July 2000**	**None**

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SIGNATURE

Marvin J. Spivak
NAME

24,913
REGISTRATION NUMBER

March 18 2002
DATE

218838US-4392-57-2-PCT

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF :

NOBUHIRO SAKIMA : ATTN: APPLICATION DIVISION

SERIAL NO: NEW U.S. PCT APPLN :
(Based on PCT/JP00/04796)

FILED: HEREWITH :

FOR: AUTOMATIC GAIN CONTROLLER:
AND WIRELESS COMMUNICATION
APPARATUS USING THE SAME

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE CLAIMS

Please amend Claim 6 to read as follows:[1]

6. (Amended) The wireless communication apparatus according to claim 2, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

Please add new Claims 7-9 as follows:

[1]A marked-up copy of the amendments is attached hereto.

7. (New) The wireless communication apparatus according to claim 3, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

8. (New) The wireless communication apparatus according to claim 4, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

9. (New) The wireless communication apparatus according to claim 5, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

REMARKS

Favorable consideration of this application, as presently amended, is respectfully requested.

The present Preliminary Amendment is submitted to cancel the multiple dependency in original Claim 6. Further, subject matter of the cancelled multiple dependency is now set forth in new dependent Claims 7-9.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.

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Marked-Up Copy
Serial No:

Amendment Filed on:
3-18-2002

IN THE CLAIMS

Please amend Claim 6 to read as follows:

--6. (Amended) The wireless communication apparatus according to [any one of claims 2 through 5] claim 2, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.--

Claims 7-9 (New).

SPECIFICATION

AUTOMATIC GAIN CONTROLLER AND WIRELESS COMMUNICATION APPARATUS USING THE SAME

TECHNICAL FIELD

The present invention relates to an automatic gain controller controlling a gain of a variable gain amplifier provided at an input of an analog-to-digital converter, and also to a wireless communication apparatus using the same.

BACKGROUND ART

Fig. 9 shows a wireless communication apparatus to which an automatic gain controller (AGC) according to the related art is applied. In the wireless communication apparatus, a signal received by an antenna 2 is amplified by an amplified 3 and a variable gain amplifier 4. An I-component and a Q-component of the amplified signal are isolated by a mixer 5. The isolated signals are then subject to analog-to-digital conversion by analog-to-digital converters 6i and 6q, respectively and are decoded by a processing unit 7. An automatic gain controller 8 calculates a difference between an output value of the analog-to-digital converter 6i and a reference value and also calculates a difference between an output value of the analog-to-digital converter 6q and the reference value so as to produce an error signal.

The automatic gain controller 8 compares the error signal with a threshold value and so as to update the gain of the variable gain amplifier 4 at predetermined intervals in accordance with a result of comparison. With this construction, signals at a level adapted to the dynamic range of the analog-to-digital converters 6i and 6q are input to the analog-to-digital converters 6i and 6q so that the precision in conversion by the analog-to-digital converters 6i and 6q is maintained at a proper level.

For example, published Japanese translation of PCT international publication for patent application No. 10-506764 discloses automatic gain control in which the gain is controlled as a result of performing comparison between the error signal and the threshold value.

In the related art, however, the gain is updated only after a predetermined period of time elapses even when the environment for reception changes as a result of, for example, a rapid variation in the level of received power. For this reason, a signal not adapted for the dynamic range of the analog-to-digital converter may be input to the analog-to-digital converter when there is a rapid change in the level of received power, resulting in decrease in the precision in conversion by the analog-to-digital converter.

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide an automatic gain controller and a wireless base station in which a precision in conversion by an analog-to-digital converter is maintained at a proper level even when an environment for reception is changed.

The present invention provides an automatic gain controller for controlling a gain of a variable gain amplifier provided at an input of an analog-to-digital converter, comprising:

a gain setting unit periodically updating the gain of the variable gain amplifier in accordance with an output from the analog-to-digital converter; and

a mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from the analog-to-digital converter, the selected operating mode being set in said gain setting unit.

According to this aspect of the invention, the gain of the variable gain amplifier is controlled in one of a plurality of operating modes characterized by difference gain updating periods in accordance with variation in the level of received power. Therefore, the gain of the variable amplifier is controlled depending on variation in an environment for communication so that the precision in conversion by the analog-to-digital converter is maintained at a proper level.

The present invention also provides a wireless communication apparatus comprising:

an antenna receiving a radio signal;

a variable gain amplifier amplifying the received signal using a variable gain;

an analog-to-digital converter converting the amplified signal into a digital signal;

a gain setting unit periodically updating the gain of the variable gain amplifier in accordance with an output from a analog-to-digital converter; and

an operating mode selection unit selecting one of a plurality of operating modes characterized by difference gain updating periods in accordance with variation in the output from said analog-to-digital converter, the selected operating mode being set in said gain setting unit.

According to this aspect of the invention, it is possible to control the gain of the variable gain amplifier in a wireless communication apparatus to which the automatic gain control is applied, depending on variation in an environment for communication. Therefore, the precision in conversion by the analog-to-digital converter in the apparatus is maintained at a proper level.

The present invention provides a wireless communication apparatus comprising:

an antenna receiving a radio signal;

an isolator isolating an I-component and a Q-component orthogonal to each other from the

received signal;

an I-component variable gain amplifier and a Q-component variable gain amplifier amplifying the isolated I-component and Q-component, respectively using a variable gain;

an I-component analog-to-digital converter and a Q-component analog-to-digital converter converting the amplified I-component and Q-component, respectively, into respective digital signals;

a gain setting unit periodically updating a gain common to said I-component variable gain amplifier and said Q-component variable gain amplifier, in accordance with outputs from said I-component analog-to-digital converter and said Q-component analog-to-digital converter; and

an operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the outputs from said I-component analog-to-digital converter and said Q-component analog-to-digital converter, the selected operating mode being set in said gain setting unit.

According to this aspect of the invention, the gain of the I-component variable gain amplifier and the gain of the Q-component variable gain amplifier are centrally controlled in a wireless communication apparatus operated on quadrature modulation. Therefore, the construction of the apparatus is simplified.

The present invention provides a wireless communication apparatus comprising:

an antenna receiving a radio signal;

an isolator isolating an I-component and a Q-component orthogonal to each other from the received signal;

an I-component variable gain amplifier and a Q-component variable gain amplifier amplifying the isolated I-component and Q-component using a variable gain;

an I-component analog-to-digital converter and a Q-component analog-to-digital converter converting the amplified I-component and Q-component into respective digital signals;

an I-component gain setting unit periodically updating a gain of said I-component variable gain amplifier in accordance with an output from said I-component analog-to-digital converter;

an I-component operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from said I-component analog-to-digital converter, the selected operating mode being set in said I-component gain setting unit;

a Q-component gain setting unit periodically updating a gain of said Q-component variable gain amplifier in accordance with an output from said Q-component analog-to-digital converter; and

a Q-component operating mode selection unit

selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from said Q-component analog-to-digital converter, the selected operating mode being set in said Q-component gain setting unit.

According to this aspect of the invention, the operating mode is selected for the I-component and the Q-component individually so that the gain of the variable gain amplifier 23i and the gain of the variable gain amplifier 23q are controlled independently.

The present invention provides a wireless communication apparatus comprising:

a first antenna and a second antenna receiving a radio signal:

a first variable gain amplifier and a second variable gain amplifier amplifying the signal received via said first antenna and second antenna, respectively;

a first analog-to-digital converter and a second analog-to-digital converter respectively converting the amplified signals into respective digital signals;

a gain setting unit periodically updating a gain common to said first variable gain amplifier and second variable gain amplifier in accordance with an output from said first analog-to-digital converter and an output from said second analog-to-digital converter; and

an operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the outputs from said first analog-to-digital converter and said second analog-to-digital converter, the selected operating mode being set in said gain setting unit.

According to this aspect of the invention, signals from the first branch and the second branch are synthesized in a wireless communication apparatus provided with diversity branches so that the gain setting unit centrally controls the gain of the first variable gain amplifier and the gain of the second variable gain amplifier. Therefore, the construction of the apparatus is simplified.

The wireless communication apparatus may further comprise a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

According to this aspect of the invention, a digital output corresponding to an analog signal amplified by the variable gain amplifier is corrected to have a digital signal corresponding to an analog signal before amplification so that an accurate received power measurement is made.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an electrical construction of a wireless communication

apparatus according to a first embodiment of the present invention.

Fig. 2 shows an operating mode of a gain setting unit 18.

Fig. 3 is a flowchart showing a flow of an automatic gain control process.

Fig. 4 is a flowchart showing a frame check process of Fig. 3 in detail.

Fig. 5 is a flowchart showing a slot check process of Fig. 3 in detail.

Fig. 6 is a flowchart showing a gain control level setting process of Fig. 3 in detail.

Fig. 7 is a block diagram showing an electrical construction of a wireless communication apparatus according to a second embodiment of the present invention.

Fig. 8 is a block diagram showing an electrical construction of a wireless communication apparatus according to a third embodiment of the present invention.

Fig. 9 shows a wireless communication apparatus according to the related art.

BEST MODE FOR CARRYING OUT THE INVENTION

The various embodiments of the invention will be described hereinafter with reference to the attached drawings.

First embodiment

Fig. 1 is a block diagram showing an electrical construction of a wireless communication

apparatus according to a first embodiment of the present invention. The wireless communication apparatus 10 comprises an antenna 11a, a mixer 12, variable gain amplifiers (VGA) 13i and 13q, analog-to-digital converters 14i and 14q, a processing unit 15, and an automatic gain controller (AGC) 19.

The antenna 11 receives a radio signal from a wireless terminal such as a portable terminal. The wireless terminal is configured to generate a radio signal by mixing an I component and a Q component by quadrature modulation. The mixer 12 detects the signal from the antenna 11 so as to retrieve the I component and the Q component by a process of isolation. The variable gain amplifiers 13i and 13q respectively amplify the I component and the Q component isolated by the mixer 12. The analog-to-digital converters 14i and 14q convert the analog signals received from the variable gain amplifiers 13i and 13q, respectively, into digital signals. The processing unit 15 performs various processes including re-synthesis of the component signals and spectrum despreading. The processing unit 15 also calculates the level of received power from output values of the analog-to-digital converters 14i and 14q, and from the level of gain control.

The automatic gain controller 19 is provided with an operation unit (I^2+Q^2) 16, a mode selection unit 17 and a gain setting unit 18, so as to control a common gain of the variable amplifiers 13i and 13q. The operation unit 16 calculates

$\Sigma(I^2+Q^2)$, based on the output values of the analog-to-digital converters 14i and 14q. The mode selection unit 17 selects a normal mode or a high-speed mode, based on the result of calculation, the normal mode and the high-speed mode being characterized by different periods of update. The gain setting unit 18 updates the common gain of the variable gain amplifiers 13i and 13q in the operating mode selected by the mode selection unit 17.

The processing unit 15 calculates the level of received power from the output values of the analog-to-digital converters 14i and 14q, and the level of gain control set by the gain setting unit 18. The processing unit 15 controls the power to be transmitted from the wireless communication apparatus in accordance with the calculated level. Alternatively, the processing unit 15 informs a remote end with which the wireless communication apparatus is communicating of the level of received power so that the remote end controls the level of transmission accordingly.

With this construction, the I component and the Q component are subject to integrated control using the operation unit 16. The gain of the variable amplifiers 13i and 13q is subject to integrated control by the gain setting unit 18. Accordingly, the construction of the apparatus is simplified. Since the operation unit 16 performs a calculation $\Sigma(I^2+Q^2)$, the I component and the Q

component are equally weighted. Therefore, appropriate performance in control is guaranteed under any environment for communication.

A description will now be given of the operation of the wireless communication apparatus with reference to Figs. 2-6.

Fig. 2 shows an operating mode of the gain setting unit 18. A frame is defined as having a duration of 10 ms and a segment of a frame produced by division-by-15 is defined as one slot. A normal mode is defined as an operating mode with a gain updating period of T1, which is relatively long. A high-speed mode is defined as an operating mode with a gain updating period of T2 (<T1), which is relative short. For example, as shown in Fig. 2, the period T1 may be equal to the duration of one frame, i.e. 10 ms. The period T2 may be equal to the duration of 5 slots, i.e. 10/3 ms. While the normal mode is being set, the gain setting unit updates the gain at the period of T1. When the high-speed mode is set, the gain setting unit updates the gain at the period of T2.

Fig. 3 is a flowchart showing a flow of AGC process. In step a1, the process is started. In step a2, I^2+Q^2 is calculated by the operation unit 16.

In step a3, I^2+Q^2 is added to one-slot sum of signal power. In step a4, a determination is made as to whether the number of data items examined reached the number of data items (for example,

5120) accommodated in one slot. When it is determined that the number of data items does not reach the total number for one slot, steps a2-a4 are repeated until the number of data items reaches the total number. When the number of data items reaches the total number, the one-slot sum of signal power is divided by the number of data items in one slot. Thus, through steps a3-a5, an average value of (I^2+Q^2) in one slot is calculated.

In step a6, a request is issued, the request being related either to a slot check process for determining whether a high-speed mode is necessary, and to a frame check process for determining whether the normal mode is necessary. When step a6 is completed, steps a7 and a8 are performed. Control is then returned to step a2 whereupon the slot-averaging process is repeated. In step a7, the slot check process for the high-speed mode is performed in accordance with the request. In step a8, the frame check process is performed in accordance with the request. Steps a7 and 8 are described later in detail with reference to Figs. 4 and 5.

In step a9, the level of gain control is set. A detailed description of step a9 will be given later with reference to Fig. 6. In step a10, the level of gain control is output from the gain setting unit 18 to the variable gain amplifiers 13i and 13q. In step a11, the whole process is terminated.

Fig. 4 is a flowchart showing the frame check process of Fig. 3 in detail. In step b1, the frame check process is started. In step b2, a determination is made as to whether there is a request for the frame check process. When it is determined that the request is not provided, the determination step b2 is repeated until a positive determination is yielded. When there is a request for the frame check process, control is turned to step b3 where one-slot average value calculated in the process of Fig. 3 is added to one-frame sum of signal power.

In step b4, a determination is made as to whether the number of slots reaches 15. When the number of slots reaches 15, control is turned to step b5 where the one-frame sum of signal power is divided by 15 so as to obtain a frame average value. Thus, through steps b3-b5, the one-frame average value is calculated.

In step b6, a determination is made as to whether the one-frame average value is lower than a lower margin Ls of a range of average values that calls for the normal mode or higher than the upper margin Us that calls for the normal mode. If a negative answer is yielded in step b4 or in step b6, control is turned to step s7 where "0", indicating a non-normal mode, is substituted in a normal operation flag NOR_FLAG. If an affirmative answer is yielded in step b6, "1", indicating the normal mode, is substituted in the normal operation flag

NOR_FLAG.

Thus, in the frame check process of Fig. 4, steps b2-b8 are repeated so that the normal operation flag NOR_FLAG is updated. Particularly, in step b6, variation in the received power is evaluated by examining the one-frame average value. The normal operation flag NOR_FLAG is set to the normal mode or the non-normal mode depending on the result of evaluation.

The upper margin Us and the lower margin Ls of a range of one-frame average value that calls for the normal mode are predetermined. The upper margin Us is selected to be higher than the lower margin Ls.

Fig. 5 is a flowchart showing the slot check process of Fig. 3 in detail. In step c1, the slot check process is started. In step c2, a determination is made as to whether there is a request for the slot check process. When it is determined that the request is not provided, the determination step c2 is repeated until a positive determination is yielded. When there is a request for the slot check process, control is turned to step c3 where a determination is made as to whether there is absence of history indicating that high-speed mode was used in the preceding slot. If the high-speed mode was used, i.e. if a negative answer is yielded in step c3, the determination steps c2 and c3 are repeated.

If it is determined that the history indicates

that the high-speed mode was not used in the preceding slot, i.e. if a positive answer is yielded in step c3, control is turned to step c4 where a determination is made as to whether the one-slot average value, determined in accordance with Fig. 3, is lower than a lower margin Lh that calls for the high-speed mode or higher than a higher margin Uh that calls for the high-speed mode. If an affirmative answer is yielded in step c4, control is turned to step c5 where a determination is made as to whether an affirmative answer is yielded for a total of n consecutive slots, where n is an integer greater than 1. If an affirmative answer is yielded in step c5, "1", indicating the high-speed mode, is substituted in a high-speed operation flag HI_FLAG in a subsequent step c6. If a negative answer is yielded in step c4 or in step c5, control is turned to step c7 where "0", indicating a non-high-speed mode, is substituted in the high-speed operation flag HI_FLAG in step c7.

Thus, in the slot check process of Fig. 5, steps c2-c7 are repeated so that the high-speed operation flag is updated. Particularly, in steps c4 and c5, variation in the received power is evaluated by examining the one-slot average value. The high-speed operation flag HI_FLAG is set to the high-speed mode or the non-hish-speed mode depending on the result of evaluation.

The upper margin Uh and the lower margin Lh of a range of one-slot average value that calls for

the high-speed mode are predetermined. The upper margin Uh is selected to be higher than the upper margin Us and the lower margin Lh is selected to be lower than the lower margin Ls.

Fig. 6 is a flowchart showing in detail the process of setting the level of gain control shown in Fig. 3. In step d1, the process of setting the level of gain control is started. In step d2, a determination is made as to whether the normal operation flag NOR_FLAG=0 and the high-speed operation flag HI_FLAG=0. That is, a determination is made as to whether both the non-normal mode and the non-high-speed mode are called for. When it is determined that the non-normal mode and the non-high-speed mode are both called for, the determination step d2 is repeated until it is determined that either the normal mode or the high-speed mode is called for.

If a negative answer is yielded in step d2, i.e. if it is determined that the normal mode or the high-speed mode is called for, control is turned to step d3 where a determination is made as to whether the high-speed operation flag HI_FLAG=1, i.e. whether the high-speed mode is called for. If it is determined that the high-speed mode is called for, control is turned to step d4 where the level of gain control is set to $\pm$XdB, where X indicates a real number greater than 1, whereupon control is returned to step d2. If it is determined in step d3 that the high-speed mode is not called for, it is

determined that the normal mode is called for. In step d5, the level of gain control is set to ±1dB so that control is returned to step d2.

According to the process of setting the level of gain control shown in Fig. 6, the level of gain control is updated in accordance with variation in the received power, by repeating steps d2-d5 after setting the level of gain control in step d4 or in step d5. Steps a3 of Fig. 3 through d3 are performed in the mode selection unit 17. Step d4 and the subsequent steps are performed in the gain setting unit 18.

As described, according to the first embodiment, the gain of the variable gain amplifier is updated in one of the two operating modes characterized by different updating periods, in accordance with variation in the received power. Thus, it is possible to control the gain of the variable gain amplifier in accordance with a change in the environment for communication. That is, even when the environment for communication changes, the analog-to-digital converters continue to receive signals adapted for the dynamic range thereof so that the precision in conversion by the analog-to-digital converters is maintained at a proper level.

One particular application is wireless base stations of a code division multiple access (CDMA) system which are normally characterized by only slight variation in the received power. In these base stations, a moderate gain control is favorable.

Therefore, the normal mode according to the invention may suitably be employed for control. In rare cases, where there is an abrupt change in the power, the high-speed mode may be employed for control so that the urgent need for keeping track of the variation is properly met. Accordingly, it is possible to effect control adapted for the environment for communication.

In the foregoing description of the first embodiment, it is assumed that quadrature modulation producing the I component and the Q component, 90° phase-displaced from each other, is employed. The present invention may find applications in other type of modulation including a simple modulation. The level of gain control in the normal mode may be other than ±1dB. Although it is assumed that the calculation $\Sigma(I^2+Q^2)$ is performed, the operation unit 16 may perform other types of calculations. For example, ΣI^2 and ΣQ^2 are calculated separately so that the common gain of the variable gain amplifiers 13i and 13q is set based on these results of calculation.

Second embodiment

Fig. 7 is a block diagram showing an electrical construction of a wireless communication apparatus according to a second embodiment of the present invention. The wireless communication apparatus 20, which is a variation of the wireless communication apparatus of the first embodiment,

comprises an antenna 21, an amplifier 21a, a mixer 22, variable gain amplifiers (VGA) 23i and 23q, analog-to-digital converters 24i and 24q, a processing unit 25, and an automatic gain controller (AGC) 29. The antenna 21, the amplifier 21a, the mixer 22, the variable gain amplifiers (VGA) 23i and 23q, the analog-to-digital converters 24i and 24q, and the processing unit 25 are the same as the corresponding components of Fig. 1 so that the description thereof is omitted.

The automatic gain controller 29 is provided with an operation unit (I^2) 26i, an operation unit (Q^2) 26q, mode selection units 27i and 27q, and gain setting units 28i and 28q so as to control the gain of the variable amplifiers 23i and 23q individually. The operation units 26i and 26q calculate square sums $\Sigma(I^2)$ and $\Sigma(Q^2)$, respectively, based on signals from the analog-to-digital converters 24i and 24q, respectively. The mode selection units 27i and 27q each selects one of a plurality of operating modes characterized by difference updating periods, based on the results of operation in the operation units 26i and 26q, respectively. The gain setting units 28i and 28q update the gain of the variable gain amplifiers 23i and 23q, respectively, in the operating mode selected by the mode selection units 27i and 27q, respectively.

With this construction, the operating mode for the I-component and that for the Q-component are

set individually so that the gain of the variable gain amplifier 23i and the gain of the variable gain amplifier 23q are controlled independently.

The operation for selecting the operating mode of the gain setting units 28i and 28q is the same as the corresponding operation according to the first embodiment shown in Figs. 2-6, so that the description thereof is omitted. Accordingly, the advantage available in the first embodiment is also available in the second embodiment. That is, the gain of the variable gain amplifier is updated in one of a plurality of operating modes characterized by different updating periods, in accordance with variation in the received power. Accordingly, the gain of the variable gain amplifier is adaptively controlled depending on the environment for communication.

Third embodiment

Fig. 8 is a block diagram showing an electrical construction of a wireless communication apparatus according to a third embodiment of the present invention. The wireless communication apparatus 30, a variation of the wireless communication apparatus of the first embodiment, comprises antennas 31 and 41, the amplifiers 31a and 41a, mixers 32 and 42, variable gain amplifiers (VGA) 33i, 33q, 43i, 43q, analog-to-digital converters 34i, 34q, 44i, 44q, a processing unit 35, and an automatic gain controller (AGC) 49.

The antennas 31, the amplifier 31a, the mixer 32, the variable gain amplifiers (VGA) 33i and 33q, and the analog-to-digital converters 34i and 34q constitute a first branch for diversity reception. These components are the same as the corresponding components of Fig. 1 so that the description thereof is omitted. The antenna 41, the amplifier 41a, the mixer 42, the variable gain amplifiers (VGA) 43i and 43q, and the analog-to-digital converters 44i and 44q constitute a second branch for diversity reception. These components are the same as the corresponding components of Fig. 1 so that the description thereof is omitted. The processing unit 35 is also the same as the corresponding unit of Fig. 1.

The automatic gain controller 49 is provided with an operation unit (I^2+Q^2) 36, an operation unit (I^2+Q^2) 46, a mode selection unit 37, a gain setting unit 38, and correction units 40 and 50, so as to control the gain of the variable gain amplifiers 33i, 33q, 43i and 43q. The operation unit 36 calculates $\Sigma(I^2+Q^2)$, based on signals from the analog-to-digital converters 34i and 34q. The operation unit 46 calculates $\Sigma(I^2+Q^2)$, based on signals from the analog-to-digital converters 44i and 44q.

A power comparison unit 39 compares power of the two branches. The mode selection unit 37 selects one of a plurality of operating modes characterized by different updating periods, based

on a result of comparison by the power comparison unit 39. The gain setting unit 38 periodically updates the common gain of the variable gain amplifiers 33i, 33q, 43i and 43q in the operating mode selected by the mode selection unit 37. The correction units 40 and 50 each stores the level of gain control effective for an initial state in which an external radio signal is not received in the corresponding one of the branches. The level of gain control effected upon reception of the radio signal is corrected by the corresponding one of the correction units 40 and 50 and set in the variable gain amplifier in the corresponding one of the branches. More specifically, each of the correction units makes a correction to cancel difference in the level of gain control required due to irregularity in products constituting each of the branches so that the total gain of the branches match.

With this construction, the I component and the Q component are synthesized by the operation units 36 and 46, whereupon the signals from the first branch and the second branch are synthesized by the power comparison unit 39, so that the gain of the variable gain amplifiers 33i, 33q, 43i and 43q are centrally controlled by the gain setting unit 38. Accordingly, the construction of the apparatus is simplified. Since the operation units 36 and 46 perform a calculation $\Sigma(I^2+Q^2)$, the I component and the Q component are equally weighted.

Therefore, proper performance in control is guaranteed under any environment for communication.

The operation of the gain setting unit 38 for selecting the operating mode is the same as the corresponding operation of the first embodiment shown in Figs. 2-6, so that the description thereof is omitted. Accordingly, the advantage available in the first embodiment is also available in the third embodiment. That is, the common gain of the variable gain amplifiers is updated in one of a plurality of operating modes characterized by different updating periods, in accordance with variation in the received power. Accordingly, the gain of the variable gain amplifiers is adaptively controlled depending on the environment for communication and the precision in conversion by the analog-to-digital converters is maintained at a proper level.

In the third embodiment, the I component and the Q component are centrally controlled. Alternatively, the components may be controlled individually as in the second embodiment. In the third embodiment, the first branch and the second branch are described as being centrally controlled. Alternatively, the branches may be controlled individually.

INDUSTRIAL APPLICABILITY

The automatic gain controller and the wireless communication apparatus according to the present

invention are suitably used in wireless base stations and wireless terminals of the CDMA system.

CLAIMS

1. An automatic gain controller for controlling a gain of a variable gain amplifier provided at an input of an analog-to-digital converter, comprising:

a gain setting unit periodically updating the gain of the variable gain amplifier in accordance with an output from the analog-to-digital converter; and

a mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from the analog-to-digital converter, the selected operating mode being set in said gain setting unit.

2. A wireless communication apparatus comprising:

an antenna receiving a radio signal;

a variable gain amplifier amplifying the received signal using a variable gain;

an analog-to-digital converter converting the amplified signal into a digital signal;

a gain setting unit periodically updating the gain of the variable gain amplifier in accordance with an output from a analog-to-digital converter; and

an operating mode selection unit selecting one of a plurality of operating modes characterized by

difference gain updating periods in accordance with variation in the output from said analog-to-digital converter, the selected operating mode being set in said gain setting unit.

3. A wireless communication apparatus comprising:

an antenna receiving a radio signal;

an isolator isolating an I-component and a Q-component orthogonal to each other from the received signal;

an I-component variable gain amplifier and a Q-component variable gain amplifier amplifying the isolated I-component and Q-component, respectively using a variable gain;

an I-component analog-to-digital converter and a Q-component analog-to-digital converter converting the amplified I-component and Q-component, respectively, into respective digital signals;

a gain setting unit periodically updating a gain common to said I-component variable gain amplifier and said Q-component variable gain amplifier, in accordance with outputs from said I-component analog-to-digital converter and said Q-component analog-to-digital converter; and

an operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the outputs from said I-component

analog-to-digital converter and said Q-component analog-to-digital converter, the selected operating mode being set in said gain setting unit.

4. A wireless communication apparatus comprising:

an antenna receiving a radio signal;

an isolator isolating an I-component and a Q-component orthogonal to each other from the received signal;

an I-component variable gain amplifier and a Q-component variable gain amplifier amplifying the isolated I-component and Q-component using a variable gain;

an I-component analog-to-digital converter and a Q-component analog-to-digital converter converting the amplified I-component and Q-component into respective digital signals;

an I-component gain setting unit periodically updating a gain of said I-component variable gain amplifier in accordance with an output from said I-component analog-to-digital converter;

an I-component operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from said I-component analog-to-digital converter, the selected operating mode being set in said I-component gain setting unit;

a Q-component gain setting unit periodically

updating a gain of said Q-component variable gain amplifier in accordance with an output from said Q-component analog-to-digital converter; and

a Q-component operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the output from said Q-component analog-to-digital converter, the selected operating mode being set in said Q-component gain setting unit.

5. A wireless communication apparatus comprising:

a first antenna and a second antenna receiving a radio signal:

a first variable gain amplifier and a second variable gain amplifier amplifying the signal received via said first antenna and second antenna, respectively;

a first analog-to-digital converter and a second analog-to-digital converter respectively converting the amplified signals into respective digital signals;

a gain setting unit periodically updating a gain common to said first variable gain amplifier and second variable gain amplifier in accordance with an output from said first analog-to-digital converter and an output from said second analog-to-digital converter; and

an operating mode selection unit selecting one

of a plurality of operating modes characterized by different gain updating periods in accordance with variation in the outputs from said first analog-to-digital converter and said second analog-to-digital converter, the selected operating mode being set in said gain setting unit.

6. The wireless communication apparatus according to any one of claims 2 through 5, further comprising a processing unit calculating a received power from the output value of the analog-to-digital converter using the gain set in the gain setting unit.

ABSTRACT

A wireless communication apparatus includes an antenna receiving a radio signal, a variable gain amplifier amplifying the received signal using a variable gain, an analog-to-digital converter converting the amplified signal into a digital signal, a gain setting unit periodically updating the gain of the variable gain amplifier in accordance with an output from the analog-to-digital converter, and an operating mode selection unit selecting one of a plurality of operating modes characterized by different gain updating periods in accordance with the output from the analog-to-digital converter, the selected operating mode being set in the gain setting unit. With this construction, the precision in conversion by the analog-to-digital converter is maintained at a proper level when an environment for signal reception varies.

FIG.1

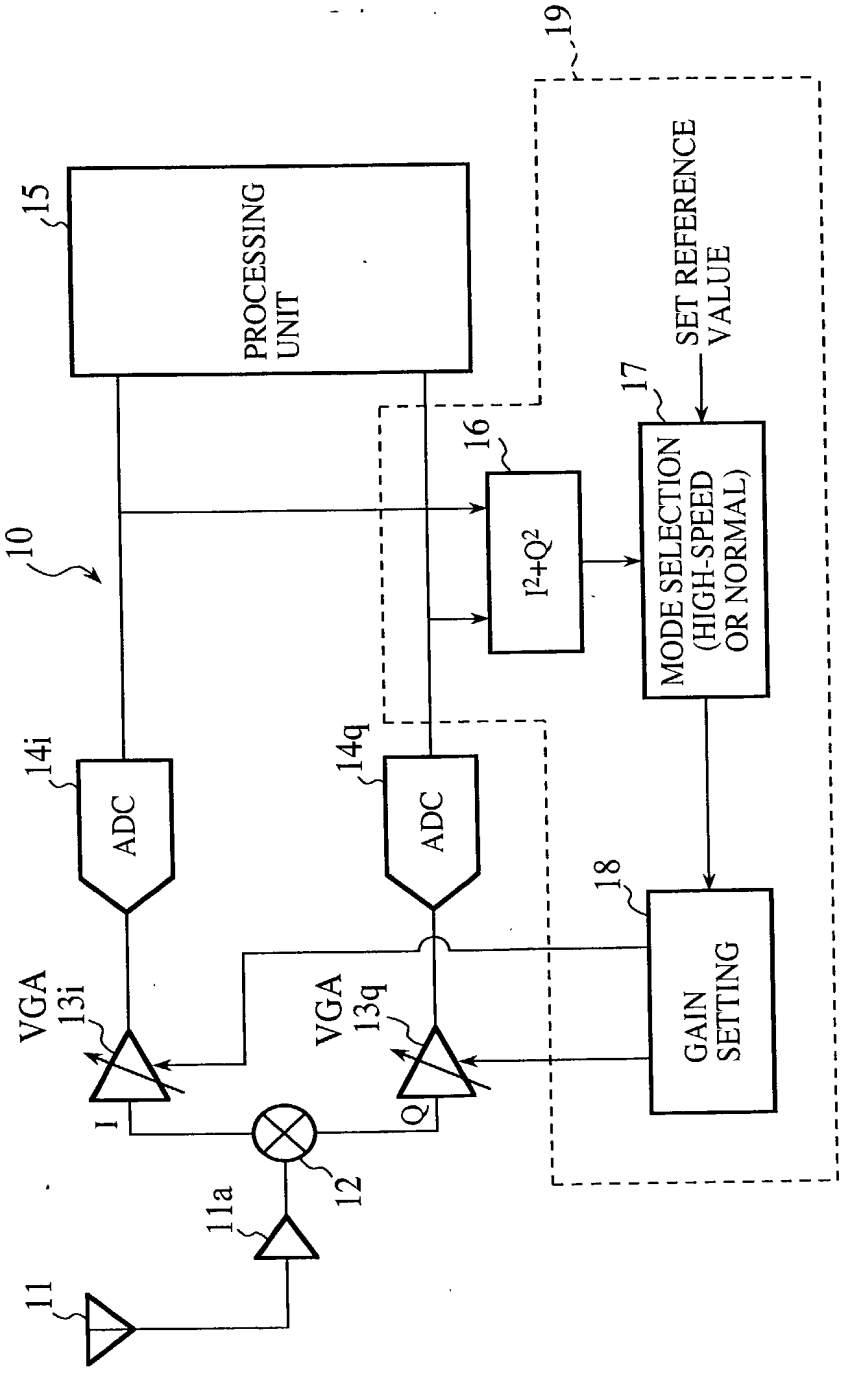
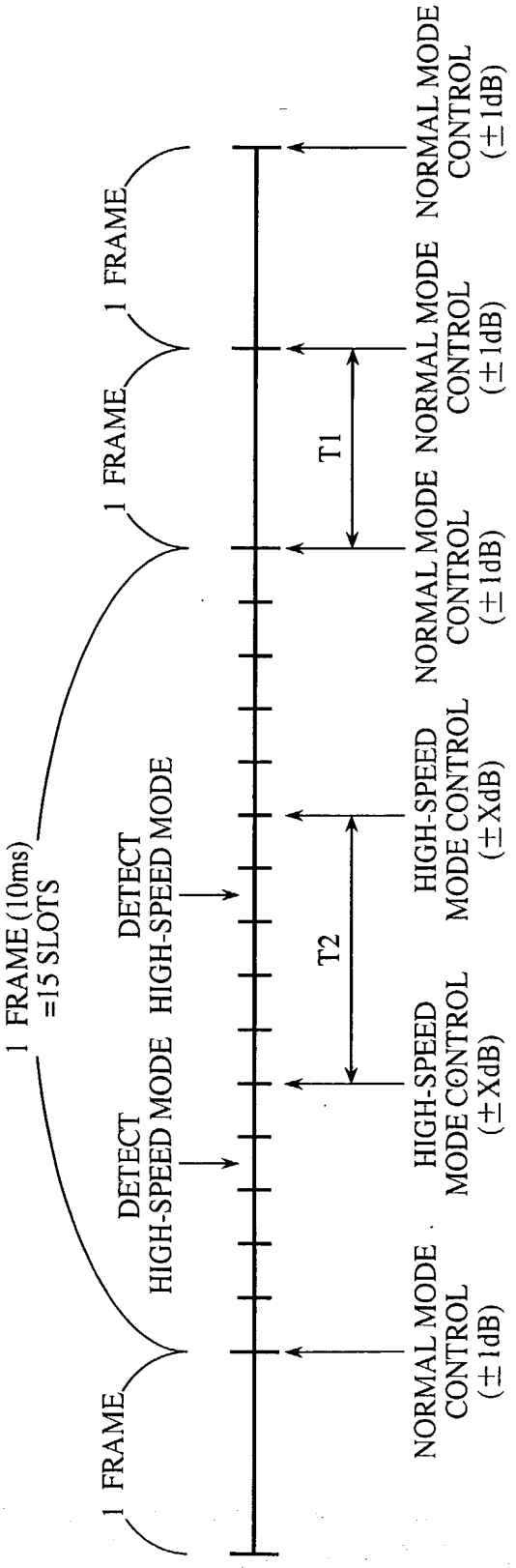


FIG.2



TIMING OF CONTROL

FIG.3

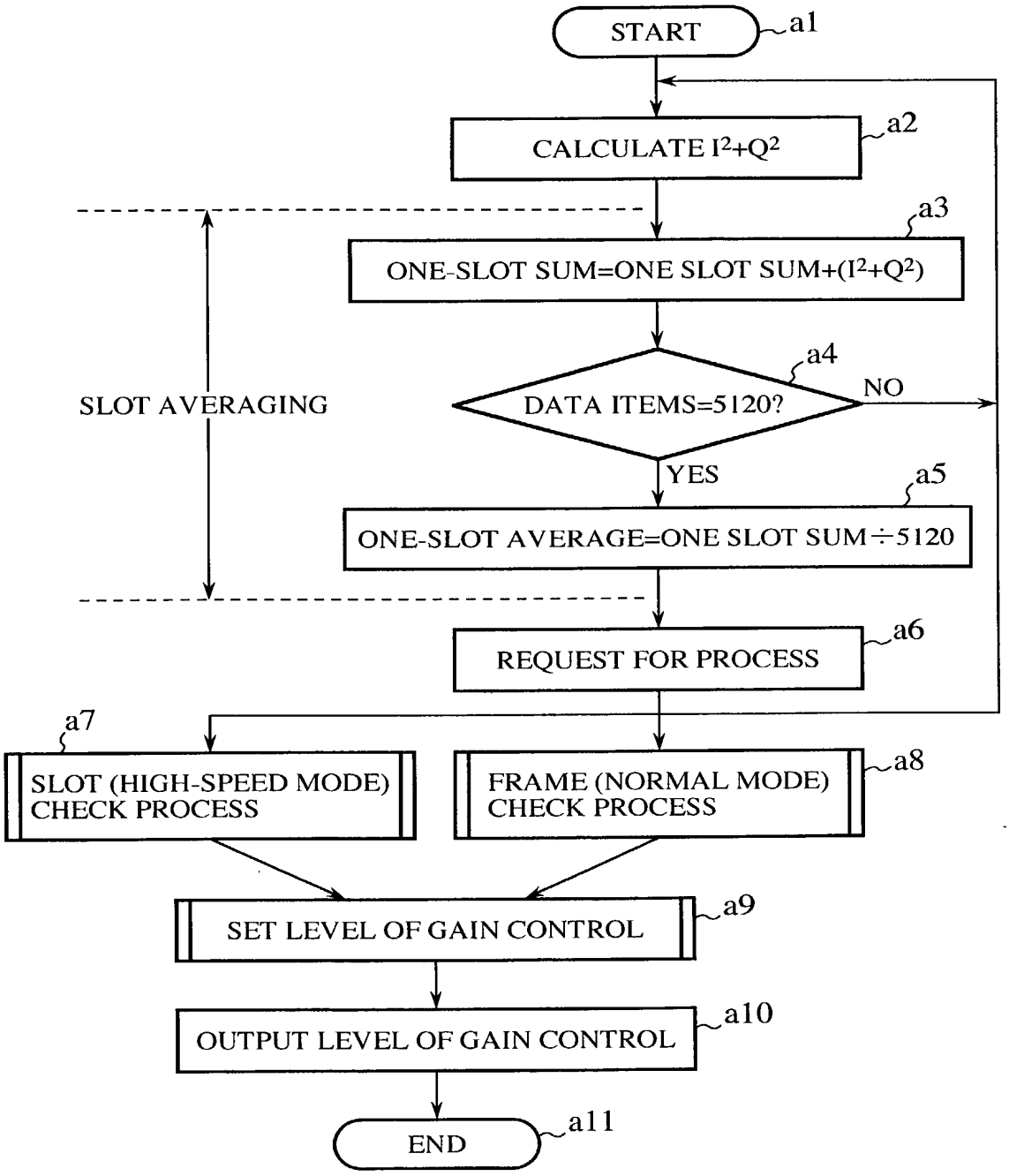

START
a1
CALCULATE I²+Q²
a2
a3
ONE-SLOT SUM=ONE SLOT SUM+(I²+Q²)
SLOT AVERAGING
a4
DATA ITEMS=5120?
NO
YES
a5
ONE-SLOT AVERAGE=ONE SLOT SUM÷5120
REQUEST FOR PROCESS
a6
a7
SLOT (HIGH-SPEED MODE) CHECK PROCESS
FRAME (NORMAL MODE) CHECK PROCESS
a8
SET LEVEL OF GAIN CONTROL
a9
OUTPUT LEVEL OF GAIN CONTROL
a10
END
a11

FIG.4

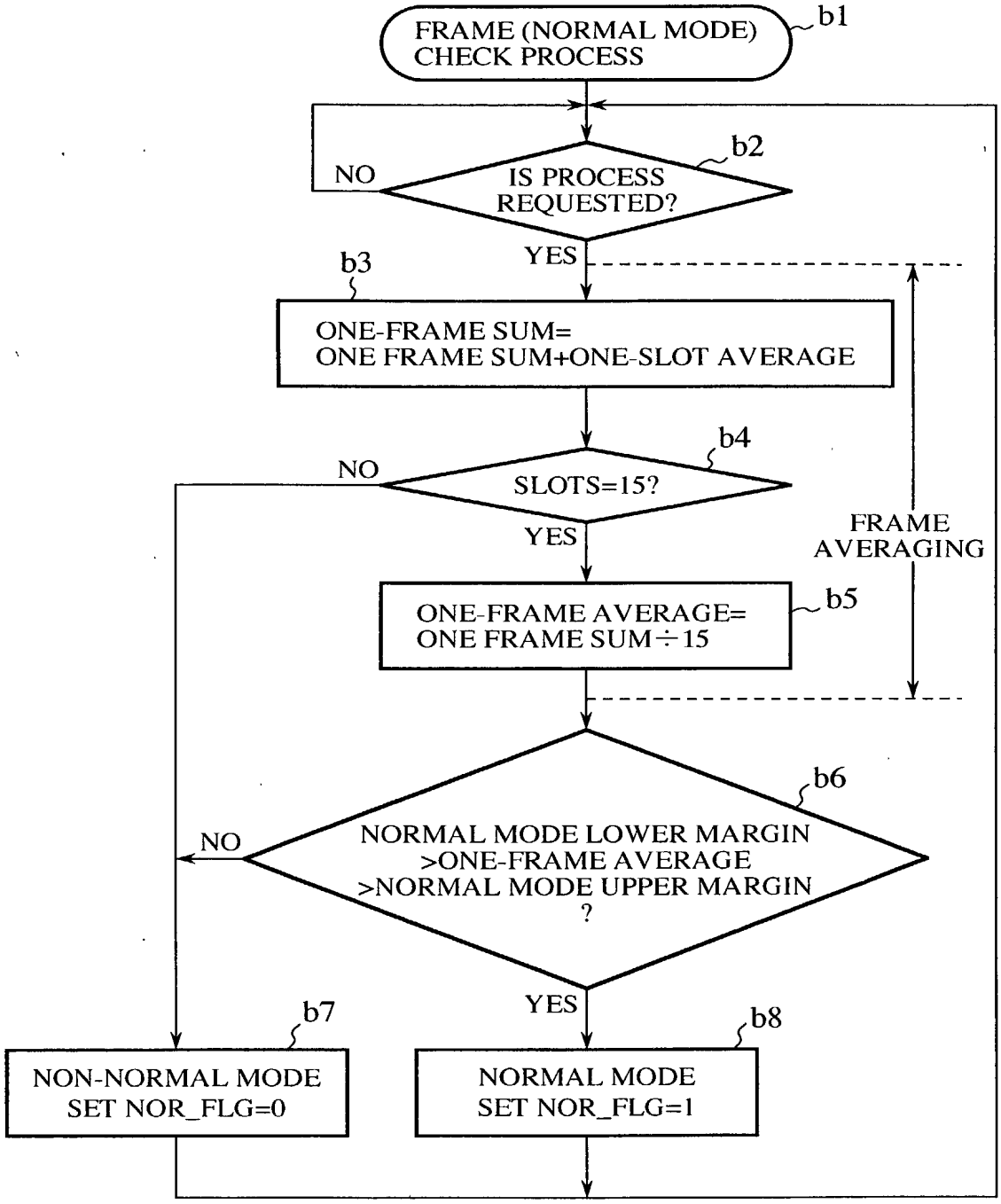

FRAME (NORMAL MODE) CHECK PROCESS
b1
b2
NO
IS PROCESS REQUESTED?
YES
b3
ONE-FRAME SUM= ONE FRAME SUM+ONE-SLOT AVERAGE
b4
NO
SLOTS=15?
YES
FRAME AVERAGING
b5
ONE-FRAME AVERAGE= ONE FRAME SUM÷15
b6
NO
NORMAL MODE LOWER MARGIN >ONE-FRAME AVERAGE >NORMAL MODE UPPER MARGIN ?
YES
b7
NON-NORMAL MODE SET NOR_FLG=0
b8
NORMAL MODE SET NOR_FLG=1

FIG.5

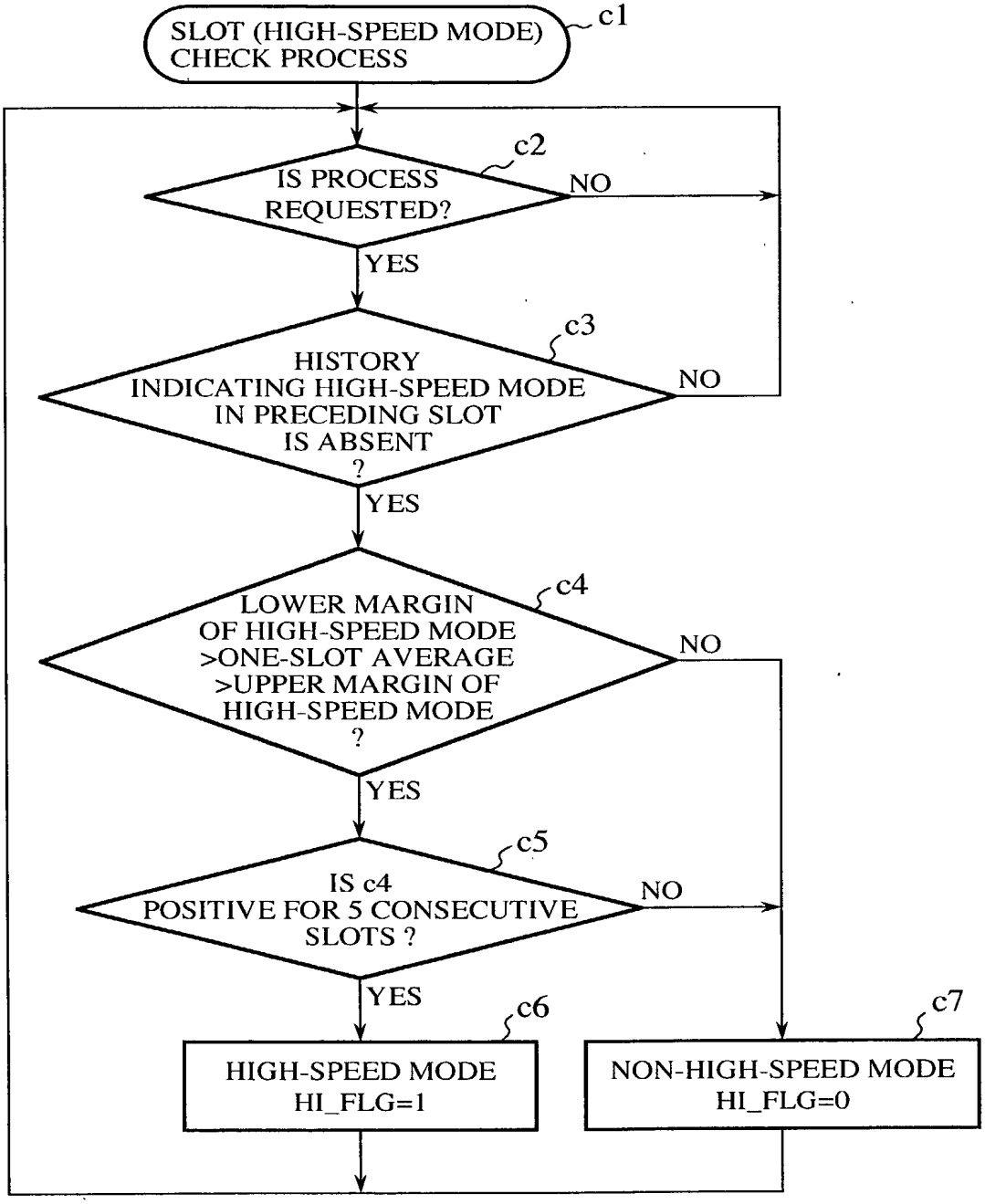

SLOT (HIGH-SPEED MODE) CHECK PROCESS
c1
IS PROCESS REQUESTED?
c2
NO
YES
HISTORY INDICATING HIGH-SPEED MODE IN PRECEDING SLOT IS ABSENT ?
c3
NO
YES
LOWER MARGIN OF HIGH-SPEED MODE >ONE-SLOT AVERAGE >UPPER MARGIN OF HIGH-SPEED MODE ?
c4
NO
YES
IS c4 POSITIVE FOR 5 CONSECUTIVE SLOTS ?
c5
NO
YES
HIGH-SPEED MODE HI_FLG=1
c6
NON-HIGH-SPEED MODE HI_FLG=0
c7

FIG.6

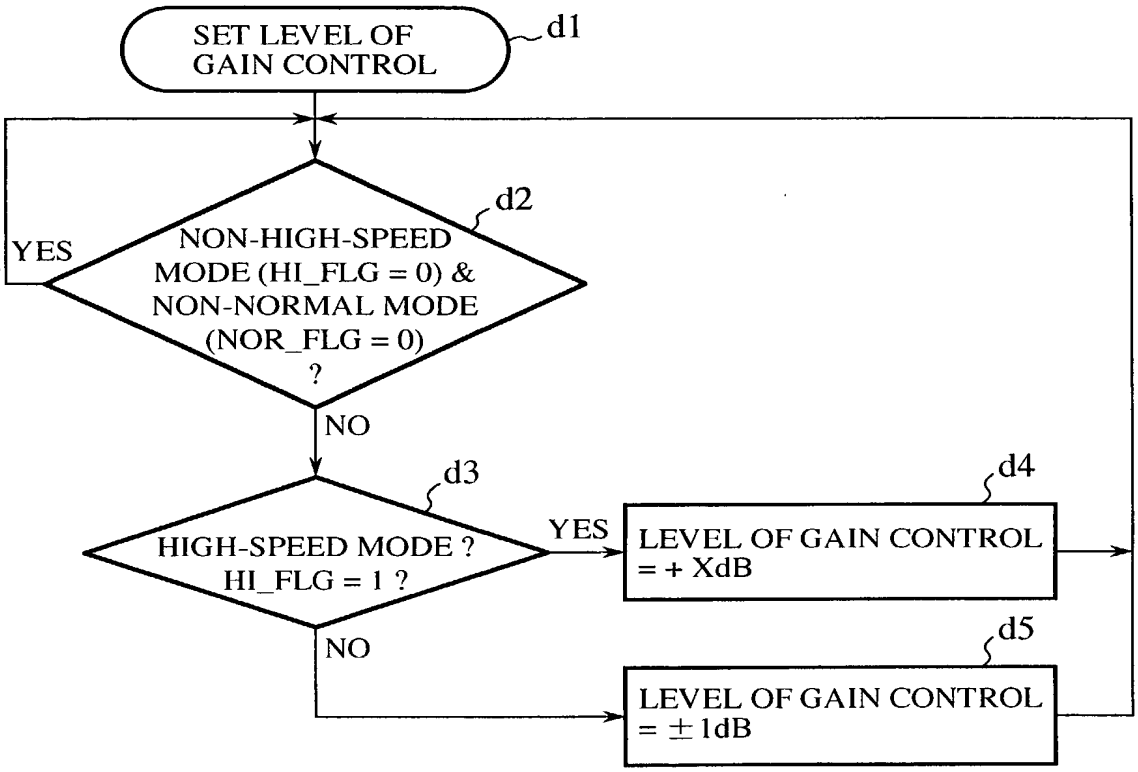


FIG.7

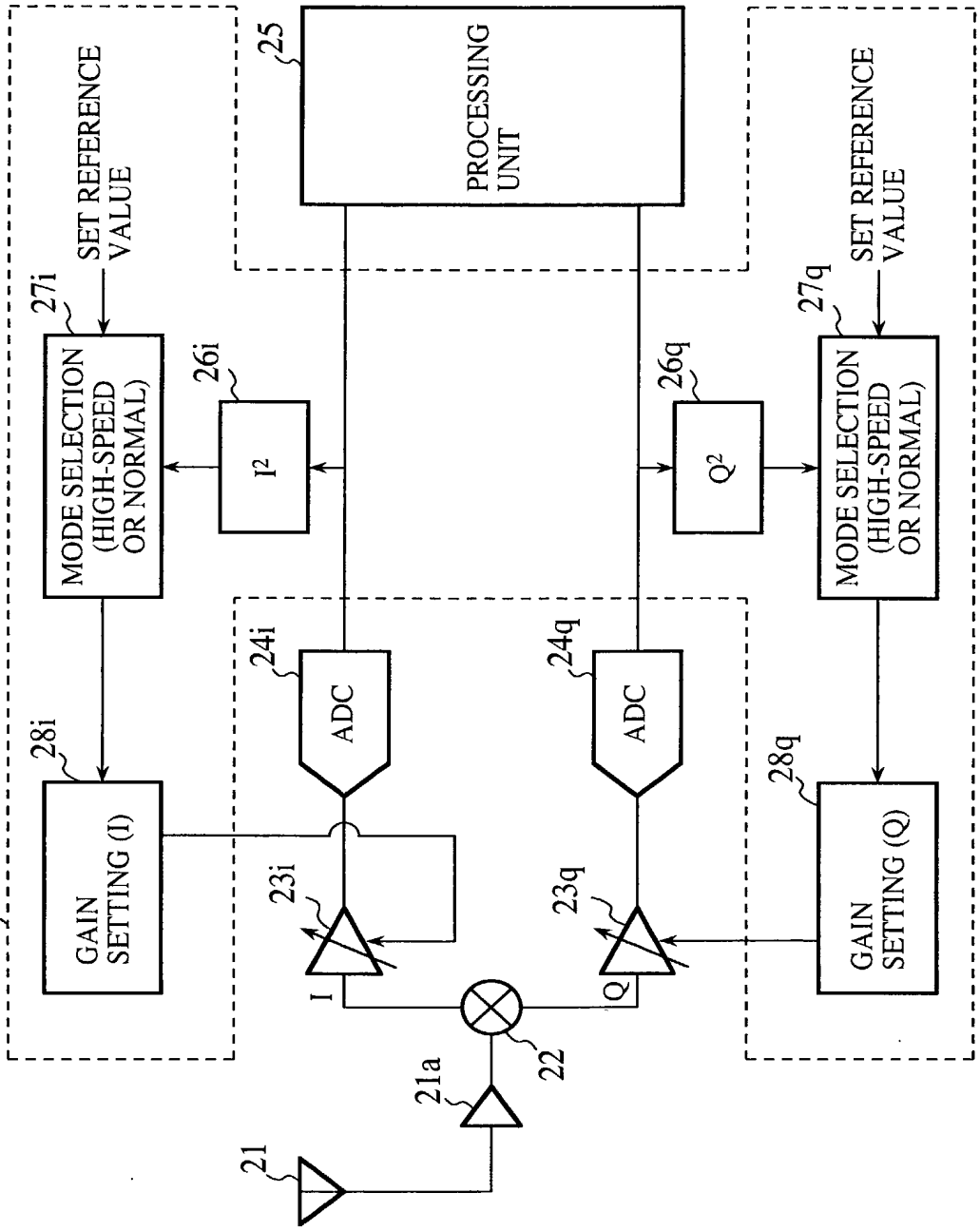

20
25
PROCESSING UNIT
SET REFERENCE VALUE
27i
MODE SELECTION (HIGH-SPEED OR NORMAL)
26i
I²
26q
Q²
27q
SET REFERENCE VALUE
MODE SELECTION (HIGH-SPEED OR NORMAL)
24i
ADC
24q
ADC
28i
GAIN SETTING (I)
28q
GAIN SETTING (Q)
29
23i
23q
I
Q
22
21a
21

FIG.8

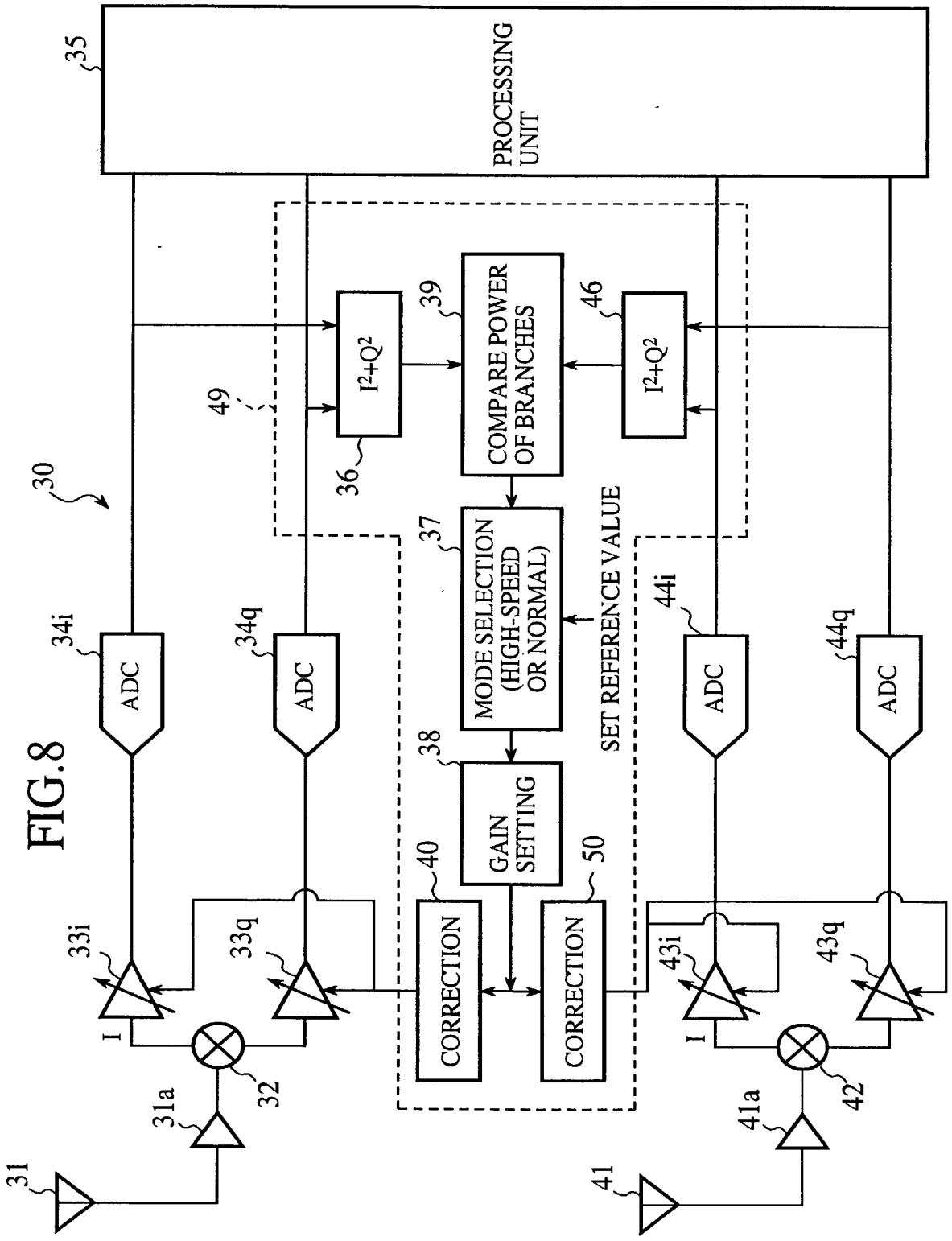
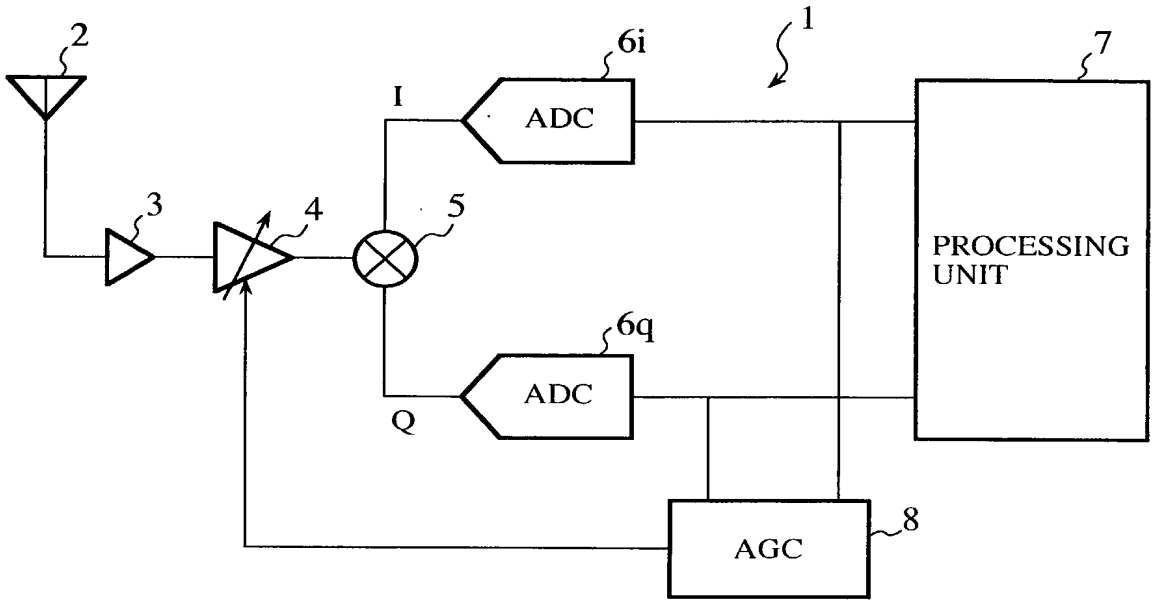

35
PROCESSING UNIT
30
49
I^2+Q^2
36
39
COMPARE POWER OF BRANCHES
46
I^2+Q^2
37
MODE SELECTION (HIGH-SPEED OR NORMAL)
SET REFERENCE VALUE
38
GAIN SETTING
40
CORRECTION
50
CORRECTION
34i
ADC
34q
ADC
44i
ADC
44q
ADC
33i
33q
43i
43q
I
I
32
42
31a
41a
31
41

FIG.9



Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者（下記の名称が複数の場合）であると信じています。

上記発明の明細書は、

☐ 本書に添付されています。

☐ ＿＿月＿＿日に提出され、米国出願番号または特許協定条約国際出願番号を＿＿＿＿＿＿とし、
（該当する場合）＿＿＿＿＿＿に訂正されました。

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

"AUTOMATIC GAIN CONTROLLER AND WIRELESS COMMUNICATION APPARATUS USING THE SAME"

the specification of which

☐ is attached hereto.

☒ was filed on July 17, 2000
as United States Application Number or
PCT International Application Number
PCT/JP00/04796 and was amended on
＿＿＿＿＿＿ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条（a）-（d）項又は365条（b）項に基づき下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365（a）項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Claimed 優先権主張 Yes はい	No いいえ
			☐	☐
			☐	☐

私は、第35編米国法典119条（e）項に基づいて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)

私は、下記の米国法典第35編120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条（c）に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

私は、私自信の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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委任状：私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。
(弁護士、または代理人の指名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: *(list name and registration number)*

022850

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(Supply similar information and signature for third and subsequent joint inventors.)